## Remarks

In the Office Action of March 1, 2004, claims 1-40 (all claims) were rejected under 35 USC § 103(a) as being unpatentable over Lehmann (U.S. Pat. No. 5,528,040) in view of Kebabian (U.S. Pat. No. 5,291,265).

Lehmann discloses a ringdown cavity (RDC) spectroscopy apparatus with an on-axis light path through the optical cavity. Lehmann does not teach the use of an off-axis light path. Kebabian discloses an absorption cell that uses an off-axis cavity configuration. The Office Action states that it would have been obvious to implement the teachings of Kebabian by directing the light beam along an off-axis path in the optical cavity of Lehmann, the supposed motivations being to create a less bulky apparatus and have a larger spacing between the mirrors while achieving the same results. Applicant respectfully disagrees.

Lehmann contraindicates use of off-axis paths. (Lehmann; col. 6, line 63 - col. 7, line 8) Thus, Lehmann states that both White and Herriott cells use off-axis optical rays and must have cross-sections on the order of 100 $cm_2$ or greater to realize long effective path lengths. In contrast, Lehmann's RDC cell is much more compact (advantage #4 in cols. 6-7). Note that Lehmann is clearly aware of off-axis configurations in multipass absorbance spectroscopy (White or Herriott cells; cf. Lehmann, col. 2, line 8 - col. 3, line 19 and col. 6, line 23 - col. 7, line 30), but expressly teaches away from their use. Lehmann recognizes that off-axis paths require large cross-section mirrors, and hence large volume cavities and a more bulky apparatus. This directly contradicts one of the Office Action's proposed motivations (a less bulky apparatus) for using off-axis paths with Lehmann's ringdown cavity. (In fact, on-axis paths between the mirrors provide the minimum volume that the beam occupies; not off-axis beams.

Kebabian describes a fixed geometry multipass cell. A light beam enters and exits the cavity through a coupling aperture 24 (a hole bored through the front mirror 22). The beam size is limited by the aperture size. (Prior to the present invention, experts in the field have relied on the use of one or more holes for getting the beam into and out of multipass cells for long path absorption measurements.) The number of passes of the beam through the cavity is limited by the geometry. (Note the equations provided in the Kebabian patent). Use of astigmatic mirror with specific curvatures allow the number of passes to be increased (usually several hundred; N=91 and 185 in the examples), but the path length is still fixed by the chosen geometry. (In contrast, the present invention's effective optical path length is in excess of 100000 passes and potentially unbounded.) Kebabian's geometry also requires a specific beam trajectory and precise alignment with the aperture location. (The mirror are otherwise completely opaque, i.e. nontransmissive.)

As correctly noted by Lehmann, such arrangements are intolerant of misalignments and sensitive to vibration (and gas turbulence inside the cell) (cf. Lehmann, col. 6, lines 52-62 and col. 7, lines 9-21). The path length or total distance that the beam propagates in the cavity before it exits depends on the trajectory (number of passes) and mirror separation, so that slight changes in alignment will change the number of passes through the cell. Misalignment and vibrations may also affect the amount of light that actually enters the cavity through the aperture. Lehmann claim that their (on-axis) RDC instrument is advantageous over the prior (off-axis) White and Herriott cells because the RDC cell has much higher accuracy (advantage #3 in col. 6) and is much less sensitive to vibration, turbulence and misalignment (advantage #5 in col. 7). Inasmuch as Kebabian's cell has the same disadvantages as White or Herriott, neither Lehmann nor any

other skilled artisan would have chosen to modify Lehmann's RDC cell with the off-axis configuration in Kebabian.

Likewise, one of applicant's goals was to reduce the sensitivity of the instrument to vibrations and changes in alignment, to allow simpler alignment routines and eliminate the need for tedious calibration procedures. In order to achieve this, constraints on the overall system alignment first had to be reduced or eliminated. An aspect of the present invention that distinguishes it from both Lehmann and Kebabian is that, rather than only a single possible alignment geometry (the on-axis path in Lehmann or the specified off-axis trajectory in Kebabian), any stable off-axis path through the cavity can be used with equivalent results. In applicant's instrument, the path length is not geometrically fixed, but depends only on mirror separation and mirror reflectivity. Beam insertion into the cavity is through a partially transmissive (typically 1% or less) mirror and is not limited by the size and position of a hole in the mirror. A specific pattern (or even a known pattern) for the multipass beam paths is not required. This fact removes much of the complications associated with astigmatic mirror cavities. None of this is taught or suggested by the cited prior art. To bring out this distinction more clearly, applicants amend the independent claims to specify that the light beam is introduced into a stable optical cavity through a partially transmissive mirror of the cavity and that the beam is directed along any off-axis path in the cavity. Even if Lehmann's instrument were to be modified with Kebabian's off-axis cell configuration (something which is not obvious and contraindicated), it would still not obtain the instrument defined in applicant's amended claims.

Another important goal of the present invention was to substantially reduce or remove the frequency selectivity of the cavity to obtain an inherently smoother and flatter optical frequency response of the cavity. This was achieved

by using the off-axis alignment to effectively decrease the cavity's longitudinal mode spacing to produce the densest possible (and nearly continuous) cavity mode transmission spectrum, effectively creating a broad band device. In particular, as described in detail from page 8, line 30 to page 10, line 25 of the application, when an off-axis alignment is created such that the multiple reflections are sufficiently spatially separated as to create a re-entrant condition in which the effective free-spectral range of the cavity is significantly narrower than the laser bandwidth (or the bandwidth of the absorption feature of interest), then the energy coupled into the cavity ceases to be a function of wavelength. Under this condition, transmission of light through the cavity becomes independent of source wavelength and thus enables high sensitivity, cavity enhanced absorption measurements without the need for complicated and expensive mode-locking techniques (as in Lehmann) or other methods (sweep and switch, etc.) for matching source wavelength to the narrow transmission peaks of an on-axis optical cavity or a talon. None of this is in the teachings of either Lehmann or Kebabian so as to provide them with any motivation to combine a stable optical cavity with a partially transmissive cavity mirror and off-axis beam insertion though the mirror. Indeed, as already noted above, Kebabian's off-axis insertion techniques (through a hole in the mirror) has alignment/ vibration constraints recognized as disadvantages by Lehmann that would first need to be overcome even if the proper motivation were to have been known. Yet it is the applicants who first conceived of an alignment-tolerant off-axis beam insertion to create a non-resonant condition in the cavity where the cavity transmission is no longer a function of wavelength.

Finally, applicants note that Lehmann's apparatus is based on cavity ringdown, which involves time domain measurements of the decay rate of light injected into the

cavity from a pulsed or chopped cw light source. Lehmann's method requires that the beam frequency correspond to a cavity resonance frequency, (Lehmann, col. 14) In the present invention, the apparatus can be operated in either a steady state (integrated cavity output) or a ringdown mode. In neither case does the present apparatus require mode matching (transverse or longitudinal). In the present invention, the free spectral range has been effectively reduced to an essentially continuous spectral transmission, thereby eliminating the need for mode matching and expensive locking techniques. And it does this without the need for a unique beam propagation trajectory required by Kebabian's configuration.

For all of these reasons, applicant's assert that the invention as set forth in the amended claims would not have been obvious in view of the prior art and is therefore patentable. Applicants request reconsideration of the application in light of the amendments and arguments presented herein. A Notice of Allowance is earnestly solicited.

CERTIFICATE OF MAILING

I hereby certify that this paper (along with any paper referred to as being attached or enclosed) is being deposited with the United States Postal Service on the date shown below with sufficient postage as first class mail in an envelope addressed to: Commissioner for Patents, Alexandria, VA 22313

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